Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Department of Animal Breeding and Genetics

Maternal behaviour and mobilization of body reserves for progeny growth

A comparative study between sows and does

Stina Burri

Examensarbete / Swedish University of Agricultural Sciences
Department of Animal Breeding and Genetics

450

Uppsala 2014

Master's Thesis, 30 hp

Master's Programme
– Animal Science

Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Department of Animal Breeding and Genetics

Maternal behaviour and mobilization of body reserves for progeny growth

A comparative study between sows and does

Stina Burri

Supervisors:

Laurianne Canario, Génétique Physiologie et Systèmes d'Elvage, INRA, Auzeville-Tolosane
Lotta Rydhmer, SLU, Department of Animal Breeding and Genetics

Examiner:

Anna Wallenbeck, SLU, Department of Animal Breeding and Genetics

Credits: 30 hp
Course title: Degree project in Animal Science
Course code: EX0556
Programme: Master's Programme - Animal Science
Level: Advanced, A2E

Place of publication: Uppsala
Year of publication: 2014
Name of series: Examensarbete / Swedish University of Agricultural Sciences, Department of Animal Breeding and Genetics, 450
On-line publicering: http://epsilon.slu.se

Key words: Maternal behaviour, piglet, kit, sow, doe, variability, survival, growth

TABLE OF CONTENTS

1. PREFACE

This masters' thesis work was carried out in the spring of 2014 in Toulouse, France and in Uppsala Sweden. The initial aim was to try and find a relation between maternal behaviour and growth and survival of animals. For this study, the rabbit was chosen as a model animal for its intensive reproduction rate, its popularity in French meat production and its mothering style. However, other than knowing that the rabbit is an altricial animal, not much work has been done on the maternal behaviour and even less on how it might affect the survival rate and growth of their young. Therefore, a second model animal was brought into the study, the pig, which has a far more studied maternal behaviour but not so much in how it might affect piglet growth and survival.

The study was initially a comparative one, where the maternal behaviour, and its potential effect on progeny growth and survival, of a precocial and an altricial animal would be compared. In this way, literature review parts that are to this day not entirely covered from a maternal behaviour point of view in rabbits, could be covered by the pig part and vice versa.

Numerous observations on rabbit behaviour and basic measurements were made on 106 rabbits provided by PECTOUL, INRA in Pompertuzat, France, where the protocol was made and entirely dedicated to this study. Observations on pig behaviour was obtained as data from a previous study carried out in 2006, partly working on sow maternal behaviour. The reason for why both species were studied and analyzed was to increase the chances of finding any significant results. Luckily and interestingly, numerous significant results were found in both species, leading to a far too big material to manage in this study report. Hence, the results were narrowed down to the results that were considered to be the most interesting ones.

I would like to thank Anna Wallenbeck, who gave me valuable feedback at the presentation, and motivated me even more to become a PhD student in animal science. I would also like to thank INRA, Toulouse, which welcomed me warmly for this stay, especially Hervé Garreau, Julien Ruesche and Elodie Balmisse from PECTOUL. I would like to dedicate a special thanks to Claude Lille-Larroucau, Sébastien Pujol, Coco Trainini, Catherine Baillot, Florence Benitez and Virginie Helies, whom I made suffer through numerous kit and doe weighing's while patiently waiting for my many behaviour observations to help me in my project, and gave me many laughs along the way. I would also like to thank my Swedish supervisor Lotta Rydhmer for all the expertise and good advices, days and nights, weekdays and weekends, towards the end of the project, entirely crucial for the making of this project. But most of all I would like to thank my French supervisor Laurianne Canario, who patiently taught me all I know about R, gave me a large amount of support and knowledge, and simply made this project possible.

Stina Burri
2014-06-26

2. ABSTRACT

The maternal behaviour of sows and does differ greatly. Pigs are precocial animals, i.e. piglets seek their mother for feed, whilst rabbits are altricial animals i.e. kits are born helpless and depend on their mothers' to come and nurse them. However, they share similar problems in commercial production from a maternal ability point of view. It is thus interesting to study if maternal behaviour has an effect on reproduction performances, and if it can be improved in pig and rabbit production in order to improve productivity. The overall aim of this thesis is to study if there is a relationship between maternal behaviour and the growth and survival of the progeny of sows and does. Since this is a very broad overall aim it has been delimited for this project report. Hence, this project focuses on doe maternal behaviour possibly affecting kit growth between birth and weaning.

Behavioural observations and general measurements were made in two batches of 106 New Zealand White (NZW) rabbit does of the 1777 INRA line from an INRA experimental herd of Pompertuzat (INRA PECTOUL, Toulouse, France). Observations were made on maternal behaviour, avoidance of human, behaviour at handling, nesting behaviour and reaction of the doe to the handling of the kits.

Does gained weight between Artificial Insemination (AI) day 12 and weighing day 26, and lost weight between weighing day 26 and weaning weighing day 33. Does that showed a strong maternal willingness, were calm during handling at the first and second weighing, were agitated during the third weighing, were passive after handling and showed a high level of fur plucking had significantly higher litter growths than does which did not show these behaviours.

The conclusion of this project is that behavioural differences were found between does which affected litter growth. High maternal willingness, calmness during handling and passivity after handling is advantageous for litter growth possibly due to a low level of stress in these does. Agitation during handling also showed to be advantageous for litter growth. Potential reasons for this are that the doe is protective of her kits, or that the does' temper is slightly more pressed close to weaning. Furthermore, a high level of fur plucking is advantageous for litter growth. However, the topic needs further research in order to clearly determine in what ways maternal behaviour, such as fur plucking, affects the mother and it is therefore hard to define what an overall advantageous doe maternal behaviour is.

Keywords: *Maternal behaviour, piglet, kit, sow, doe, variability, survival, growth*

3. SAMMANFATTNING

Grisen och kaninens modersbeteende skiljer sig markant från varandra. Grisen är precocial, vilket innebär att kultingar söker upp suggan för att få föda medan kaninen är altricial där ungarna föds hjälplösa och modern söker upp dem för att ge di. Dock delar gris- och kaninproducenter liknande problem i den kommersiella produktionen ur ett modersbeteendeperspektiv. Därför är det intressant att utreda om modersbeteende har en effekt på reproduktiva förmågor hos djuren och om det kan förbättras inom gris och kaninproduktionen för att därigenom förbättra produktiviteten. Det övergripande målet med denna uppsats är att undersöka om det finns ett samband mellan modersbeteende, tillväxt och överlevnad av kaninungar och kultingar. Eftersom detta är ett väldigt brett mål, fokuserar detta projekt på hur kaninhonans modersbeteende eventuellt har en inverkan på kulltillväxten mellan födsel och avvänjning.

Beteendeobservationer och generella mätningar gjordes under två kullar på 106 New Zealand White (NZW) kaninhonor från den genetiska linjen 1777 INRA på en experimentell besättning tillhörande INRA i Pompertuzat (INRA PECTOUL, Toulouse, Frankrike). Observationer gjordes på modersbeteende, rädsla för människan, beteende vid hantering, benägenhet att bygga bo och moderns reaktion vid hanteringen av ungar.

Kaninhonor gick upp i vikt mellan den artificiella insemineringen (AI) dag 12 och dag 26 för att sedan tappa vikt mellan dag 26 och avvänjning dag 33. Kaninhonor som visade stark moderlig villighet, var lugna vid hantering under det första och andra vägningstillfället, var rastlösa under det tredje vägningstillfället, var passiva efter hantering samt visade en hög grad av pälsplockning, hade en signifikant högre kulltillväxt än de som inte visade dessa beteenden.

Slutsatsen av detta projekt är att beteendeskillnader påträffades mellan kaninhonor vilka påverkade kulltillväxten. Stark moderlig villighet, lugn vid hantering och passivitet efter hantering visade sig vara fördelaktigt för kulltillväxt, troligtvis på grund av en allmänt låg stressnivå hos dessa kaninhonor. Rastlöshet vid hantering visade sig också vara fördelaktigt för kulltillväxt. Anledningar till detta kan förslagsvis antingen vara på grund av att honan är överbeskyddande av sina ungar, eller att honan från början är något irriterad på grund av platsbristen och den höga aktivitetsgrad som sker i buren så tätt inpå avvänjning. Vidare är en hög grad pälsplockning fördelaktigt för kulltillväxten. Ämnet behöver dock vidare efterforskning för att kunna klargöra på vilket sätt modersbeteende, såsom en hög grad pälsplockning, påverkar modern. Det är således i nuläget svårt att definiera vad ett allmänt fördelaktigt modersbeteende är hos en kaninhona.

Nyckelord: Modersbeteende, kulting, kaninunge, sugga, kaninhona, variabilitet, överlevnad, tillväxt

4. RÉSUMÉ

Le comportement maternel de la truie diffère de celui de la lapine. Le cochon est un animal précoce, les porcelets vont vers leurs mère pour se nourrir, tandis que le lapin est un animal altricial, les lapereaux sont nés impuissants et dépendent entièrement de leurs mères pour s'alimenter. Malgré cela, en production commerciale, les mêmes problèmes peuvent être rencontrés au niveau des aptitudes maternelles. C'est pourquoi il est intéressant d'étudier si le comportement maternel a un effet sur les performances reproductrices et s'il peut améliorer la productivité en production lapine et porcine. L'objectif général de ce mémoire est d'étudier la possibilité d'une relation d'une part entre le comportement maternel et d'autre part la croissance et la survie des porcelets et lapereaux. Puisque cet objectif est très vaste, il a été délimité pour ce rapport de projet. L'objectif délimité est donc d'étudier comment le comportement maternel de la lapine peut affecter la croissance de la portée entre la mise-bas et le sevrage.

Des observations de comportement ont été faites et des mesures générales ont été prises sur deux parités consécutives constituant de 106 lapines de race New Zealand White (NZW) de la lignée 1777 INRA à Pompertuzat (INRA PECTOUL, Toulouse, France). Les observations de comportement ont été faites sur le comportement maternel, la méfiance à l'homme, la réaction à la manipulation par l'homme, la construction de nid ainsi que la réaction à la manipulation des jeunes par l'homme.

Les lapines ont pris du poids entre l'insémination artificielle (AI) au 12ème et la pesée du 26ème jour, puis elles en ont perdu entre 26ème et le sevrage au 33ème jour. Les lapines qui avaient une volonté maternelle forte, étaient calmes lors de la première et la deuxième pesée, étaient agitées lors de la troisième pesée, étaient passives après avoir été manipulées et s'arrachaient le plus de poils, avaient un gain de poids de portée plus élevé que les lapines qui ne montraient pas ces comportements.

La conclusion de ce projet est que des différences de comportement maternel ont été trouvées entre lapines dont le comportement avait un effet sur la croissance de portée. Une volonté maternelle forte, un comportement calme à la manipulation par l'homme et un comportement passif après la manipulation par l'homme sont tous des comportements avantageux pour une croissance de portée plus élevé, probablement grâce à un niveau de stress moins élevé chez ces lapines. Un comportement agité pendant la manipulation par l'homme est aussi considéré avantageux pour une croissance de portée plus forte. Ceci peut être dû à un comportement protecteur de la lapine ou un tempérament de la lapine généralement plus mauvais si près du sevrage. Ensuite, un comportement d'arrachage de poils élevé mène aussi à une croissance de portée plus élevé. Cependant, le sujet doit d'avantage être plus étudié afin de déterminer réellement comment le comportement maternel, comme celui de l'arrachage de poils, affecte la lapine. C'est pour cela qu'il est difficile de définir ce qu'est un comportement maternel général avantageux.

Mots clés : Comportement maternel, porcelet, lapereau, truie, lapine, variabilité, survie, croissance

5. INTRODUCTION

The domestic pig (*Sus scrofa domesticus*) and the rabbit (*Oryctolagus cuniculus*) are two differing kinds of production animals in several aspects. For instance, they differ in meat properties, production and management, and popularity on the market. Both species are however high rate production animals, since sows wean on average 24.4 piglets per sow and year (BPEX, 2012) and does wean on average 60 kits per doe and year (Lebas *et al.* 1997).

There is always an ambition to increase productivity in animal husbandry in order to make the production more profitable. One way to increase the pig and rabbit productivity of today is to select animals that have good maternal abilities. This has already been done in both pigs and rabbits and has shown to be beneficial for productivity (Wischner *et al.* 2009; Blasco *et al.* 1993). However, the wish to further increase productivity, by for instance implementing selection on larger litters, has led to a higher rate of pre-weaning mortality in pigs (Gill, 2007), possibly risking bringing the production back to square one in increasing productivity.

How maternal behaviour could potentially improve production has, to the authors' knowledge, not yet been widely researched. The maternal behaviour of rabbits and sows differ since pigs are precocial and rabbits altricial, meaning the sow stays close to its piglets during early lactation while does implement an "absentee" mothering style (Gonzàles-Mariscal *et al.* 2007). Interestingly, rabbit and pig producers encounter some of the same production problems, which will be discussed hereafter, from a maternal ability point of view, even though both species show such different types of maternal strategies.

Both sows and does invest body resources between birth and weaning of their progeny, where sows typically lose body weight, and does undergo a certain body weight change (Gilbert *et al.* 2012; Maertens *et al.* 2006) additionally, does pluck their fur. It is interesting to see whether these changes and behaviours affect the survival and growth of their progeny. Another factor possibly affecting the survival and growth of the young is fearfulness towards the human handlers. Rabbits are typically fearful towards humans, and should logically show some sort of discomfort upon human handling (Crowell-Davis, 2007). Furthermore fear has shown to be disadvantageous for productivity in both pig and rabbit production (Bilkó & Altbäcker, 2000; Hemsworth *et al.* 1989). In other words, this would mean that animals being calm and passive when exposed to fearful events would have a higher survival and growth of their progeny.

The following study treats numerous behaviours which are analyzed with different weight variables in both pigs and rabbits. The choice of animal species was first of all made so that two species with different maternal strategies could be compared which, despite their differences share some of the same problems in commercial production. Secondly, due to the fairly undiscovered effects of maternal behaviour in rabbits, so that previous pig studies could give some background information in the field. And thirdly, due to the initial believe that few or no significant results would be found during this study alone. However, due to the actual finding of a large amount of significant results in does, the results have been narrowed down so that only the most interesting significant rabbit results are presented in this report

The overall aim of this study is to gain more knowledge in rabbit maternal behaviour and to try and find a potential relation between maternal behaviour and growth and survival of pig and rabbit progenies.

6. AIM AND HYPOTHESIS

The overall aim of this project is to study a potential relationship between maternal behaviour and the growth and survival of the progeny of sows and does. However, in order to delimit the overall aim, this study focuses on doe maternal behaviour possibly affecting kit growth between birth and weaning.

The hypothesis of this study is that does show variation in maternal behaviour and that some behaviours are more beneficial for litter growth than others, namely;

1) High maternal willingness
2) Calmness
3) Agitation during handling
4) Passivity after handling
5) High level of fur plucking

7. LITTERATURE REVIEW

7.1. Introduction

The ancestor of the domestic pig, the wild boar (*Sus scrofa*) lives in a complex social environment during lactation together with other lactating sows and their piglets (Špinka, 2006) which are highly precocial (Dellmeier & Friend, 1991). The expression of maternal behaviour of wild boars and modern domestic pigs share great similarities (Jensen, 1986). The maternal abilities of the sow determine piglet survival and growth during lactation (Grandinson *et al.* 2003) in conventional, as well as in free-range productions. In organic pig farming, where the goal is to resemble the pigs' natural habitat, outdoor access is mandatory, piglets are weaned later, kept in larger groups and mostly fed on sow milk only. Thus, the maternal abilities of the sow are of even greater importance, since the piglet care in free-range is managed by the sow, instead of the farmer (Wallenbeck *et al.* 2008). The maternal care of sows is somewhat limited, given that sows do not lick their progenies as other mammalians do.

The rabbit lives in a large colony where it digs burrows in which the different parts of the colony live (Lebas *et al.* 1997). Every colony has social groups of approximately 2-8 individuals (Crowell-Davis, 2007). In organic production, rabbits are housed in pairs or small groups, as to respect the natural social structure (Casseland, C., stockperson, Arwen Rabbit, personal communication, January 21, 2014). The maternal behaviour of the doe has undergone few changes since it was domesticated as recently as 400 years ago (Gonzàles-Mariscal *et al.* 2007). The doe has evolved a different way of interacting with its kits post-parturition compared to most other mammals, a behaviour sometimes called the "absentee" mothering style (Gonzàles-Mariscal *et al.* 2007). A complex nest to keep the kits warm and protected from predators is built before kindling (parturition). After kindling, the doe provides her kits with very restricted maternal care (Gonzáles-Mariscal *et al.* 1998) although the kits are altricial (Rödel *et al.* 2008), i.e. born blind, helpless and without fur.

Hereafter, the literature review will include topics such as reproduction in production, reproduction performances of sows and does, female investment in reproduction, behaviour of sows and does, limits of expression of maternal behaviour in a production environment, and genetics of maternal behaviour.

7.2. Reproduction in production

A sow is serviced in oestrus either by natural service (NS) or artificial insemination (AI) for the first time at an age of 7-8 months. The timing of the service is of great importance since the sow ovulates for an average of 50 hours (normally ranging between 32-69 hours) (Gill, 2007). Synchronization of ovulation can be obtained when sows are injected with a GnRH agonist resulting in oestrus between 36 and 48 hours after treatment (Stewart *et al.* 2010). The sow gestation length can vary between 110-120 days, but the average duration is 115 days, they are then transferred to individual farrowing crates in many European countries (Algers & Uvnäs-Moberg, 2007). Sows are heated again at first oestrus after weaning of piglets (27 days).

It is long known that the rabbit is an induced ovulator (Lebas *et al.* 1997; Heape, 1905), meaning that coitus induces ovulation, and that the doe thus has indefinite and irregular oestrus cycles

(Gonzàlez-Mariscal *et al.* 2007). Artificial Insemination (AI) (in both pigs and rabbits) is often used in European farms in order to maximize reproductive performances and optimize human resources (Dal Bosco *et al.* 2011; Gonzáles-Mariscal *et al.* 2007). There are 3 typical reproduction rates in rabbit husbandry, namely; 1) extensive, where does nurse their kits for an average of 5-6 weeks and are rebred at weaning, 2) semi-intensive, where does are serviced 10-20 days post-parturition, and 3) intensive; where does are rebred directly after parturition, hence taking advantage of the heat they are in (Lebas *et al.* 1997). The semi-intensive reproduction rate is most commonly used in Europe and the average number of days for rebreeding is 11 days post-parturition (Mugnai *et al.* 2009). Does are inseminated for the first time when they reach around 80% of their adult weight (120-130 days of age) (Lebas *et al.* 1997). To induce ovulation at AI, gonadotropin-releasing hormone (GnRH) is often used, either by intravenous injection or added directly to the semen, as a substitute for the lack of nervous stimuli that the buck usually brings the doe (Dal Bosco *et al.* 2011; Lebas *et al.* 1997). The doe kindles after 31-33 days of gestation (Coureaud *et al.* 2008; González-Mariscal *et al.* 2007; Moreki, 2007).

7.3. Mortality, birth weight, and weaning of piglets and kits in production

The average litter size of French Large White sows is 13.7, and the average birth weight of a piglet is 1.4 kg (Bouquet *et al.* 2014). After farrowing, piglets are typically cross-fostered in order to, equalize litter-sizes (Heim *et al.* 2012). Piglets gain on average 910 g/day from birth to weaning (Pigwin, 2013). In a study by KilBride et al. (2012), the average number of stillborn piglets was 6.5% and pre-weaning mortality in live born piglets was 12.5% with 55% caused by crushing. This pre-weaning mortality in live born piglets is in accordance with the EU average in the industry statistics of the British Pig Executive yearbook (BPEX, 2012). Some years ago, the main causes of piglet death at birth and in early lactation in the French Large White population from INRA, were stillbirth (28.1%), crushing (20.1%), weakness (39.5%), savaging (5.7%), malformation (0.9%) and other causes (5.7%) (Canario 2006). Cronin & van Amerongen (1991) suggested that a modified farrowing crate (enriched with straw and a hessian bag as a cover over the nest) improves the maternal behaviour in primiparous sows since it increases the nest-building behaviour prevalence, the vocal responses from the sow reacting to their piglets distress calls/grunts, and decreases piglet mortality. In a master thesis study conducted by Isberg (2013), it was concluded that the number of weaned piglets per sow and year is highly correlated with management factors. She also concluded that factors such as herd, litter appearance (i.e. size, vitality, and homogeneity), number of functional teats and udder health of the sow correlate with the number of weaned piglets per litter. The average weaning age for piglets in Europe is 27 days, and the average number of piglets reared per sow and year in Europe is 24.4 (BPEX, 2012). The average weaning weight of a piglet is approximately 8 kg (Milligan *et al.* 2002).

In rabbit, the average daily weight gain of a kit ranges between 30-40g during the nursing period in semi-intensive production systems (Lebas *et al.* 1997). Litter size can range from 1 to 20 kits but the average is around 7-9 kits in the New Zeeland White breed in France (Moreki, 2007; Lebas *et al.* 1997). The litter size is correlated to the birth weight of the kits which is variable between 40g up to 70g (Poigner *et al.* 2000). It is common practice to perform kit adoptions, where litter sizes are evened out, so that all does have approximately the same amount of kits of approximately the same weight in a production system (Moreki, 2007). In a study made by

Coureaud and colleagues (2000) the mortality rate of new-born kits was 9.6% and 81% of the losses occurred within the first 10 days of the kits' lives. The main causes of death for the kits were starvation, digestive dysfunctions, wounds, unknown, circulatory/respiratory dysfunctions and soiling of the nest; starvation being the most common and soiling of the nest the least common. Weaning of the kits normally occurs at between 26-30 days (in rational European production) i.e. when the kits have reached a weight of 500g (Moreki, 2007). In a standard semi-intensive reproduction rate, between 55 and 65 kits are weaned per doe per year (Lebas *et al.* 1997). The average weaning weight per kit is 887g (Lebas *et al.* 1997).

7.4. Female investment in reproduction: mobilisation of body resources

Mobilisation of body resources is of great importance for high-rate production animals. Genetic selection for increased litter sizes in sows increases the mothers' milk production demand (Gilbert *et al.* 2012; Drake *et al.* 2008). This results in an increased energetic demand, causing a substantial weight loss in early lactation (Drake *et al.* 2008). Sows have two ways of solving this problem, according to Gilbert *et al.* (2012); either they increase their feed-intake and mobilise less energy, or they eat less and mobilise more energy. This was supported in the same study by showing that a low-Residual Feed Intake (RFI) line had a reduced daily feed intake which lead to major changes in body reserves, higher weight gain in litters, lower sow weight and leaner farrowing. In a study by Valros *et al.* (2004), they found that increased oxytocin concentrations lead to a greater mobilisation of body resources, and thus to a faster piglet growth. The same study showed that sows in a catabolic state, the sow had higher NEFA concentrations which were positively correlated with piglet daily weight gain and sow weight loss.

Genetic selection for increased litter sizes in does increases the milk production demand from the mother (Pascual *et al.* 2013). Does that show higher body-fat losses during lactation have a higher milk yield (Maertens *et al.* 2006). The body condition of the doe undergoes daily changes during its reproductive cycle according to its genetic abilities, peaking at 10 days before kindling and being lowest at parturition (Pascual *et al.* 2013). Maertens *et al.* (2006) state that the factors having the largest impact on milk yield are non-nutritional, instead it is lactation stage, litter size, degree of overlapping gestations, parity order and heat stress that are the most important factors. Does with overlapping gestations tend to have a less successful kit survival than does that do not (Martinez-Gómez *et al.* 2004). It has been shown that nutrition has some effect on the litter weight of the subsequent litter, especially in primiparous does (Martens *et al.* 2006).

7.5. Behaviour of sows and does

7.5.1. Maternal behaviour of sows and does in nature

When domestic sows are kept in free range, the maternal behaviour observed around parturition is typically divided into a well-known 6 stage pattern, namely: 1) Nest-site seeking; a behaviour performed within 24 h pre-parturition where the sow wanders off from the group to find a suitable, often sheltered, place to farrow. 2) Nest-building; where the sow usually digs a hole in this chosen spot, and gathers soft materials (such as grass) in the centre of the hole. 3)

Farrowing; which takes place between 3-7 h after the nest-building, where the sow typically gets up, turns around to sniff the new-born piglets and changes position from one side to another. 4) Nest-occupation; where the sow and her piglets stay confined to the nest for approximately 9 days after farrowing (Jensen, 1986). Within the first hours postpartum, it is crucial that the piglets adapt to the nursing process (i.e. respond to maternal grunts, find teat etc.) of the sow (Algers, 1993). Every day, approximately 21 nursing events occur with an average bout length of 6.5 minutes (Yun *et al.* 2013). The average daily milk yield for a sow is 8 kg (Laws *et al.* 2009). 5) Social integration of the young; where the piglets are introduced to the rest of the flock after approximately 2 weeks of age. And, 6) Weaning; which occurs between 14 and 17 weeks of age (Jensen, 1986).

After two weeks of pregnancy (Deutsch, 1957), the doe performs a first nest-building behaviour where material such as straw, hay or other suitable material is gathered into a "straw nest", preferably in an earthy hole in the ground. Either immediately after the straw nest has been terminated, or after a time period of hours up to days, the "maternal nest" is built with fur that the doe plucks off her body (González-Mariscal*et al.* 2007; Zarrow *et al.* 1963). The doe nurses her kits on average 1.26 times per day (Selzer *et al.* 2004) for 3.5 minutes on average (Hoy & Selzer, 2002; Bilkó & Altbäcker, 2000) and has an average daily milk yield of 250 g (Maertens *et al.* 2006). Does learn to attach their responsiveness given to them by the stimulation of the young, despite the short duration of each nursing bout (Gonzáles-Mariscal *et al.* 1998). It is crucial for the kits to obtain milk during the neonatal period since the nursing opportunities are so few, and last for such a short period of time. When the kits cannot compete with the rest of the brood or miss a nursing event, the outcome is often fatal (Fortun-Lamothe *et al.* 2007). After kindling, does typically rebreed after a postpartum oestrus, the lack of daylight during wintertime disrupts the reproduction cycle in nature (González-Mariscal *et al.* 2007). Weaning occurs after approximately a month (Coureaud *et al.* 2008; González-Mariscal *et al.* 2007).

7.5.2. Maternal behaviour in a production environment

In commercial pig housing, maternal behaviour is of great importance, according to Wischner *et al.* (2009) and Arey and Sancha (1996), which found that it has a beneficial effect on productivity. Nest building behaviour is seen to commence around 24h pre-parturition (Cronin *et al.* 1991). In crates, behaviours such as bar biting and frequent posture changing is interpreted as restlessness and, to some extent, irritated agitation during this period (Cronin & Smith, 1991) since nest building is very limited in the crated sow. In a study by Fraser *et al.* (1997) where a conventional crate, measuring 430mm (the width of the sow's body) was compared to a crate 3 times as large, results showed little differences in changes of posture as well as in time spent in different positions (turning around was however not possible in the conventional crate) during farrowing between the two crates. However, welfare is strongly decreased in a traditional farrowing crate as opposed to in a farrowing pen (Pedersen *et al.* 2013). During lactation, sows are in many European countries typically kept in the farrowing crates that restrict their movements (Šilerová *et al.* 2006) in order to reduce the mortality rate of piglets that die from crushing (Blackshaw *et al.* 1994). However, a majority of large-scale studies show that piglet mortality is not increased in loose housed sows with well-designed pens (Pedersen *et al.* 2013).

In a conventional production system, does are commonly housed in individual standard wire mesh cages measuring around 60-65cm in width, 40-50cm in length and 34-38cm in height

(Mugnai *et al.* 2009). They can breed in these cages all year around. Farmers typically provide the does with boxes and shavings to build their nests and kindle (González-Mariscal *et al.* 2007). When the doe leaves the nest after nursing, the kits huddle together, and cover themselves in the nest to save energy. In nature, the doe usually closes the nest entrance in order to protect the kits from predators, this is however not possible in commercial circumstances (Baumann *et al.* 2005a). As a result to this, the doe visits the nest more than usual, which may disrupt the kits' thermal regulation, the does' lactation physiology, and may lead to a digestive overload in the kits (Coureaud *et al.* 2000). Also, kits that try to suckle during the short visits may be dragged out to the does' cage, away from the warmth of the nest, and may not survive (Baumann *et al.* 2005). The nest box is put in place 2-3 days before kindling (Moreki, 2007). The boxes are approximately 30cm x 30cm x 30cm of area, are attached outside the cage, and have sliding hatches that can be opened and closed by handlers (Baumann *et al.* 2005a). The most beneficial light schedule in rabbit production has shown to be 14 hours of daily light, which is why artificial lightning is commonly used (Moreki, 2007).

7.5.3. Fearfulness towards humans in sows and does

Fearful animals are likely to utilize both behavioural and physiological responses if exposed to the close presence of a human, in order to try to cope with the challenge that this stressor brings to them (Scott *et al.* 2009; Hemsworth & Barnett, 2000). A significant finding, made by Hemsworth *et al.* (1989) is that the handlers' behaviour towards the pig has a strong effect on the level of fear of humans. They found this by showing that if most of the physical interactions between pig and handler were negative, there was a high probability that the pig had a high level of fear of humans. Conversely, brief positive handling from animal handlers has been shown to lead to a lower level of fear of humans (Hemsworth & Barnett, 2000). Janczak *et al.* (2003) found that 8 week old female piglets showing lower fear of humans were predicted to have more adaptive maternal behaviour and higher reproductive success. Moreover, it has been found that there are significant negative correlations between the level of fear of humans and the reproductive performance in sows (Hemsworth *et al.* 1989). A reduced number of stillborn piglets and live born piglets dying within the first three days is associated with reduced fear towards humans (Janczak *et al.* 2003). In order to assess human-pig relationship on a farm, behavioural tests may be conducted. A test where sows approaches the handlers' hand, or a test where sows in group are approached by a handler, show good repeatability and give good measures on the level of fear towards humans in the sows (Scott *et al.* 2009). Janczak and colleagues (2003) suggest that selection for sows with higher maternal success may be obtained by the development of methods based on the sows early age fear responses to humans.

Rabbits are typically initially afraid of humans, and may therefore show fearful behaviour such as: freezing, running away or attacking human (Crowell-Davis, 2007). However, if rabbits are exposed to positive handling or even only as much as human smell during the first neonatal week, they have shown to become tamer and less fearful towards humans when fully grown (Dúcs *et al.* 2009; Jezierski & Konecka, 1996). In order to test fearfulness in rabbits, one can do as Bilkó and Altbäcker (2000) which placed one rabbit at a time in a separate wire mesh cage, left it for 5 minutes so that it could be habituated while the observer was hiding while waiting, and finally approached the cage while putting one hand on one of the walls, timing the latency before the rabbit touched the hand with its nose. For the neonatal handling to be successful in making the rabbits less fearful, it must, according to Csatádi and colleagues (2005), be conducted within 30 minutes after the nursing during the kits' first week. Due to further research on the sensitivity of the kits during their first neonatal week, findings have shown that kits are able to distinguish between familiar and unfamiliar humans (Csatádi *et al.* 2007). There is a great positive effect of being handled as a kit and reproductive performances, where the conception rate was nearly doubled when compared to non-handled does pre-weaning in a study by Bilkó and Altbäcker (2000). Moreover, it has been shown that early handling of kits also reduces mortality rate and influences the growth rate positively (Jezierski & Konecka, 1996). It is proposed that handling is an important aspect of successful rabbit production, since properly timed handling may increase breeding performance (Dúcs *et al.* 2009).

In both pig and rabbit production, a high level of fear of humans is correlated with lower reproductive performance (Bilkó & Altbäcker, 2000; Hemsworth *et al.* 1989). Moreover, the kind of handling that stockpersons perform is important for the level of fear of human in both species (Dúcs *et al.* 2009; Hemsworth *et al.* 1989). Positive handling decreased the level of fear of humans, whilst aversive handling increased it.

7.5.4. The mothers' reaction to the manipulation of progeny by human

Both sows and does react to human manipulation of their young (Vangen *et al.* 2005), in does however, this has to the authors' knowledge not yet been studied in depth.

In 2003, Grandinson and colleagues studied "the sow's response towards the stockperson handling of piglets" among other behavioural traits which they hypothesized would be correlated to the sow's maternal abilities. The overall objective of their study was to investigate whether or not there was a genetic background to these behaviours, and to estimate a genetic and phenotypic relation to piglet survival. The tests that they carried out were in connection to regular treatments, e.g. castration or iron supplementation of piglets on day 4 post-parturition. If piglets did not need any of the regular treatments, the handler was supposed to pick up one piglet at a time and squeeze it gently until it screamed. The body posture of the sow before the handling of the piglet was recorded, as was the reaction, e.g. change of posture, of the sow after the piglet had been handled, and the whole behaviour was then scored according to Fig. 1. Vangen and colleagues (2005) also expected there would be a genetic variance for a behavioural trait they called: "reaction to piglet screaming when handled". By means of a questionnaire, the researchers got farmers' answers to the question "How often is the sow reacting with excitement or agitation when you handle the piglets in a way that makes them scream?" which they were instructed to answer on a scale from 1 to 7, 1 being always, and 7 being never. Grandinson and colleagues (2003) found little genetic correlation in the handling test. The results may have been biased in this study however, as the stockperson did not have the time to wait until a sow was laying down to perform the test, due to that the observations were made in relation to regular treatments. Thus, a sow that was initially standing could then only receive score 0, and it was therefore impossible to analyse how she would have reacted if she initially was lying down.

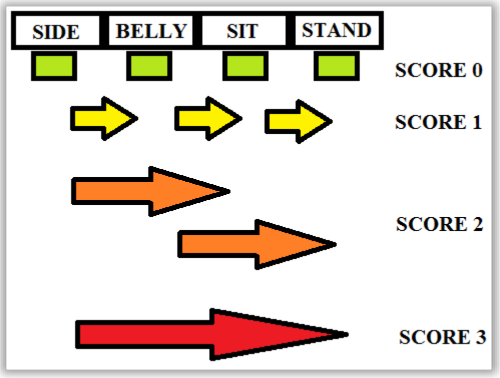

Figure 1. Description of how Grandinson et al. (2003) measured the reaction of the sow to the handling of her piglet. Score 0). If no reaction was recorded compared to the initial one. Score 1) If 1 reaction step was observed compared to the initial one. Score 2) If 2 reaction steps were observed compared to the initial one. Score 3) If 3 reaction steps were observed compared to the initial one (Modified from Grandinson et al. 2003).

The does' reaction to the handling of her kits has been poorly researched to the authors' knowledge. Nonetheless, there is reason to believe that a reaction can be seen in the doe. During ethological observations, some reactions such as: scratching, curious behaviour, anxiety, approach, and moving away, could be observed in the does.

7.6 Limits of expression of maternal behaviour of mothers under farming condition

It is interesting to compare the maternal behaviour of sows and does since both species are successful animals in production although their maternal strategies differ from each other in many aspects. Even if the strategies differ between the species they are still seen to be of great importance for the level of success in the production. The level to which the natural behaviour is acknowledged in the different production systems also differs, and it is thus also interesting to study which these are, why they are acknowledged or ignored, and in which ways this affects the animals. Both pigs and rabbits live in larger groups in their natural habitat (Lebas *et al.* 1997; Špinka, 2006). In conventional production systems however, they are both housed individually (Mugnai *et al.* 2009; Algers & Uvnäs-Moberg, 2007). The reason for this is to gain more control over the production, the young, and the mothers during early production stages. The sow stays with her piglets post-parturition to nurse them on average 21 times a day for an average length of 6.5 minutes (Yun *et al.* 2013), and the doe nurses her kits only 1.26 times per day (Selzer *et al.* 2004) for an average length of 3.5 minutes (Hoy & Selzer, 2002; Bilkó & Altbäcker, 2000), both nursing strategies are nonetheless successful and both are equally crucial for the survival and growth of the young. The piglets have free access to the sow whenever it is time for nursing, whereas the doe is depending on stockpersons opening the hatch to get access to the kits in the nest. Thus, the doe cannot choose when to nurse the kits, even though there is only one nursing per day. Nest-building, however different, has shown to be a strong maternal instinct in both species (Jensen, 1986; Zarrow *et al.* 1963). It is standard procedure to provide does with materials so that they may build their nests pre-parturition. Even in the crated sow, where the nest-building behaviour is harder to exercise, the nest-building behaviour is commonly seen. However, both the sow and the doe feel an urge to dig in the ground, a natural behaviour impossible to satisfy in conventional production.

Natural weaning occurs around 16 weeks for piglets (Jensen, 1986), and around 4 weeks for kits (Coureaud *et al.* 2008; González-Mariscal *et al.* 2007), in production however, the young of both species are weaned at around 27 days (BPEX, 2012; Moreki, 2007). The fact that the doe is an induced ovulator (Heape, 1905) makes the AI much less complex than the service (AI or natural) of the sow where the oestrus cycle needs to be timed to perfection in order to be as successful as possible (Gill, 2007). Both species differ in age of first service, length of gestations, and litter sizes (Table 1.). This explains the difference in progeny weaned per mother per year, where the sows wean on average 24 piglets per sow and year (BPEX, 2012) and does wean on average 60 kits per doe and year (Lebas *et al.* 1997). Post-natal mortality is a problem for both sows and does (KilBride *et al.* 2012; Coureaud *et al.* 2000). The main causes for post-natal mortality in piglets are; stillbirths, crushing, starvation and savaging (Grandinson *et al.* 2010), whereas the main causes for post-natal mortality in kits are; starvation, digestive dysfunctions, wounds, and circulatory/respiratory dysfunctions (Coureaud *et al.* 2000).

Table 1. Comparative descriptive reproductive statistics between sows and does

Trait	**Sow mean values[1]**	**Doe mean values[1]**
Age of first service	7.5 months	125 days
Length of gestation (days)	115	32
Litter size (number born alive and stillborn)	13.7	8
Progeny birth weight (g)	1041	55
Progeny weaning weight (g)	8000	887
Number weaned progeny/mother and year	24	60
Average daily gain of progeny until weaning (g)	912	35
Weaning age (days)	27	28

1 See text for references

7.7 Genetics of maternal behaviour

Grandinson and colleagues (2003) used a piglet scream test to test the maternal abilities of their purebred Yorkshire sows. A tape recorder was placed in the sows' pen (when she wasn't nursing) on which they started playing a piglet scream, and the sows' reaction to the distress call was then recorded. They also carried out a piglet handling test (see part 6.5.4). The results showed low heritabilities for the scream test ($h^2 = 0.06$) and the piglet handling test ($h^2 = 0.01$). However, they found a genetic correlation indicating that a selection for strong response in the scream test would increase the survival rate of the piglets. Løvendahl and colleagues (2005) carried out a similar test where they tested cross bred Yorkshire and Landrace sows' response to screaming piglets. They estimated the heritability for maternal behaviour to be low ($h^2 = 0.08$). Vangen and colleagues (2005) however, estimated higher heritabilities for maternal behaviour based on a handling test in pigs, where $h^2 = 0.16$ was estimated for Norwegian herds (purebred Landrace) and $h^2 = 0.12$ was estimated for Finnish herds (purebred Landrace and Yorkshires). The reason for this may be that farmers did observations on their own sows, and answered a questionnaire that was given to them. The effect of the person in charge of recording behaviour can be important. For the heritabilities to be completely accurate, a single person, with no knowledge about the individual sows, would have had to perform the behavioural observations. Vangen and colleagues (2005) think there is a possibility that this has biased their results to some extent, but they are convinced that the participating farmers, closely connected to the breeding organisation, are relatively objective. Another reason for higher heritabilities may be the longer observation period where each farmer had to summarise all of the sows' behaviours into the questionnaire. In this way, random environmental factors were not as important in the questionnaire answers compared to a test where such factors are hard to fit in a statistical model. Gäde and colleagues (2008) estimated the heritability for maternal ability in sows to be $h^2 = 0.05$. They defined maternal ability on Large White, Landrace and crosses of them both with 5 different traits, namely; 1) behaviour during farrowing, 2) behaviour during laying down, 3) nursing behaviour, 4) reaction to piglet's screams, and 5) crushed piglets. The crossbred sows showed a higher rate of crushing and savaging, and hade worse maternal abilities, compared to the pure bred sows.

In rabbit research, heritability for maternal behaviour in the doe has to the author's knowledge not been researched. There is however a demand for improved maternal behaviour in production rabbits (Casseland, C., stockperson, Arwen Rabbit, personal communication, January 21, 2014).

The author's overall perception of introducing maternal behaviour into breeding programmes is that it needs further research, that the tests need to be further refined in order to be of high value for the research and breeding, and that there is a demand for including maternal behaviour in breeding programmes as it looks today.

8. MATERIAL AND METHODS

Sow data were obtained from a previous study on an INRA experimental herd of Magneraud (INRA, GENESI, Charentes-Maritimes, France) where some maternal behaviour data was collected. These data were analysed but were later considered to be of les importance to this study than the doe data. Hence, the sow parts will not be mentioned further in this project report.

8.1 Doe data

8.1.1 Animals and conditions

Initially, 106 New Zealand White (NZW) does of the 1777 INRA line, from an INRA experimental herd in Pompertuzat (INRA PECTOUL, Toulouse, France) born on 21st of April and 2nd of June 2013 were followed during two consecutive kit batches. The does were kept indoors in two kinds of individual cages with lowered nests; Chabeauti (68cm x 39cm x 31cm) with nest boxes (23cm x 39cm x 41cm), and Extrona (75cm x 40cm x 37cm) with nest boxes (25cm x 40cm x 47cm). The does had free access to the nest boxes and shavings for nest-building 2 days pre-parturition.

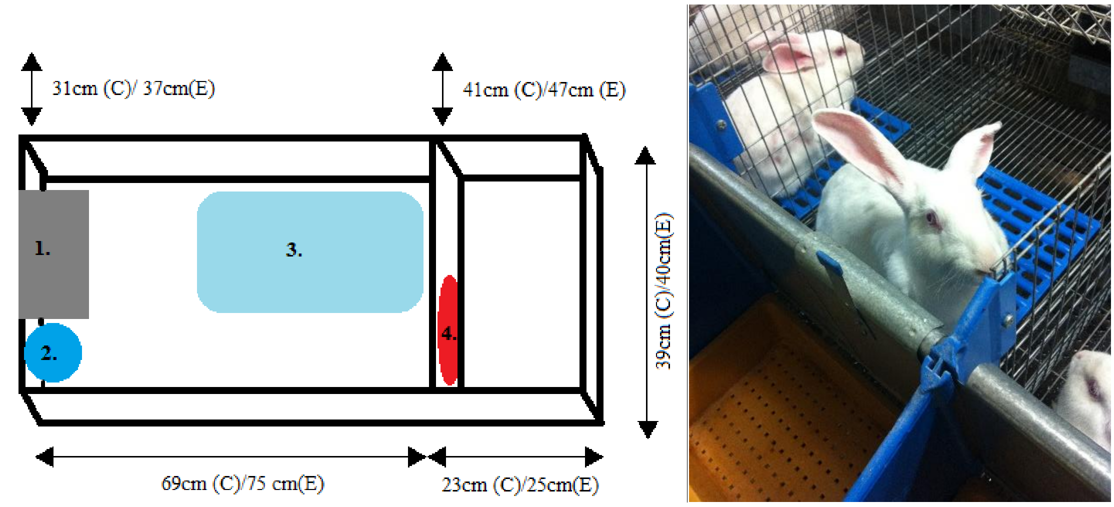

Figure 3. Schematic representation and photo of the Extrona cages. (C) Indicates Chabeauti cage measurements and (E) indicates Extrona cage measurements. 1) Feed station, 2) water dispenser, 3) plastic part for resting paws, and 4) hatch entrance to nest.

The nest hatch was closed post-parturition and opened once a day every morning for 10 days. After 10 days, the hatch stayed opened. Does were provided two kinds of feed during batch 1 and 2 in maternity and water *ad libitum*. Stabipro maternity feed is composed for the does (contents: 16.5% crude cellulose, 17.2% crude protein, 8.4% crude ash, 2.8% crude fat, 1.1% calcium, 0.7% phosphor, and 0.3% sodium). The feed also contained additives such as vitamins and antibiotics (sulfadimethoxine 465mg/kg and Trimethropine 100mg/kg). Stabientero fattening feed was given 21 days post-parturition until weaning and is primarily composed for the kits (contents: 19.2% crude cellulose, 15% crude protein, 8.5% crude ash, 2.9% crude fat, 1.1% calcium, 0.65% phosphor, and 0.2% sodium). The feed also contained additives such as vitamins and coccidiostatics (Robenidine chlorohydrate 66mg/kg and Tiamuline 52mg/kg). The light regime was held at 8/16 L/D until 6 days before the AI when a stressed light regime was implicated to 16/8 L/D and kept until 6 days after the AI where the regular light regime was reinstated. The temperature was held constant at 19±1°C. Artificial Insemination (AI) with NZW buck semen from the 1777 INRA line and injection of GnRH took place on the 1st of January for the first kit batch and the 19th of February for the second kit batch.

8.1.2 General measurements

Measurements were recorded according to the scheme in Table 2. Does were weighted at three occurrences: AI, 2 weeks later and at weaning, i.e. 1 week later.

Table 2. Schedule of observations first and second batch.

Day	Observation
0	Reaction to human approach test Nest-building behaviour prevalence
0-2	Parturitions
3	Maternal behaviour observations Weighing of stillborn kits
4	Maternal behaviour observations Identification, weighing 1 and adoption of kits Weighing of dead kits
5	Maternal behaviour observations Reaction of the doe to the manipulation of kits Weighing of dead kits
6	Reaction to human approach test Weighing of dead kits
11	Maternal behaviour observations Weighing 2 of kits Reaction of the doe to the manipulation of kits
12	AI of does Weighing 1 of does Doe behaviour at human handling
13 - 24	Daily instant observation of number of kits leaving the nest
26	Weighing 2 of does Doe behaviour at human handling
33	Weighing 3 of does Doe behaviour at human handling Reaction of the doe to the manipulation of kits
34	Weaning of kits Weighing 3 of kits

The health of the does was also recorded and different kinds of conditions were recorded (minor and major paw damage, minor and major digestive trouble, minor and major coryza (nasal mucous discharge), abnormal teeth growth etc.). Kits were weighted at 3 occurrences: 2 days after birth (± 1 day since parturitions occurred over 3 days), 1 week later (when the hatch was opened for good), and 3 weeks later at weaning. All dead kits were weighted, and the cage in which they were held was registered. The number of live born, stillborn and sacrificed kits was registered for each doe. After the hatch was opened, the number of kits leaving the nest was recorded once in the morning on a daily basis during 11 days.

8.1.3 Reaction to human approach test and handling by human

An avoidance of human test was performed 1 day pre-parturition and repeated 1 week later (Table 3).

Table 3. Ethogram for test of human avoidance

Doe reaction to the opening of the cage	
Freeze	Doe stands or sits completely still with a fearful expression in the eyes
Back away	Doe moves to the back of the cage
Stomp	Doe stomps with one of the back-paws
Curiosity	Doe approaches the opening of the cage exploring, may stand on her back-paws
No reaction	Doe is calm and shows no particular reaction
Doe reaction to the human touch	
Freeze	Doe stands or sits completely still with a fearful expression in the eyes
Back away	Doe moves to the back of the cage
Stomp	Doe stomps with one of the back-paws
Curiosity	Doe approaches the human hand exploring, may stand on her back-paws
No reaction	Doe is calm and shows no particular reaction
Calmness	
At 15s	Doe has regained calmness after 15s

Table 4. Ethogram for doe behaviour at handling

Before weighing	
Freeze	Doe stands or sits completely still with a fearful expression in the eyes
Calm	Doe is calm
During weighing	
Agitated	Doe performs minor scratching behavior with the hind-legs
Very agitated	Doe performs major scratching behavior with the hind-legs, possibly vocalizing
Calm	Doe is calm during the entire weighing
After weighing	
Nervous/ Calm	Nervous: Doe is agitated and restless Calm: Doe shows no particular reaction
Active/Passive	Active: Doe is active (moves, eats, drinks, grooms herself etc.) Passive: Doe stands or sits still
Fearful/ Confident	Fearful: Doe goes straight to the back of the cage, fearful expression in the eyes Confident: Doe is calm and not fearful

Avoidance was recorded in 3 stages; 1) An unknown stockperson approached a cage, 2) the stockperson opened the cage, and 3) the stockperson put down its hand into the cage. In the repeated fear test, a 4^{th} stage was added where the doe was touched on the back with a rapid hand movement. Finally, it was recorded if the doe had regained calmness after 15s. The does' behaviour while being handled by a stockperson was recorded during weighing in 3 steps; before (calm or freeze), during (calm, agitated or very agitated), and after (nervous/calm, active/passive, or fearful/confident) (Table 4).

8.1.4 Nesting behaviour

One day pre-parturition the nest-building activity was assessed through nest quality, recorded in 3 different levels; no nest, small nest, or large nest (Table 5). The fur of the does that had kits was observed during the second batch of kits. The does were given 4 different scores ranging from 0-3 depending on the amount of fur that was on their body (3 = poor fur, 2 = major plucking, 1 = minor plucking and 0 = full fur).

Table 5. Observation of nesting-prevalence

Nest	**Description**
No nest	The shavings have remained untouched, have had some minor scratching, or the nest-box serves as a litter
Little nest	The shavings have been scratched and somewhat moved into the middle of the nest-box, possibly mixed with some fur
Big nest	The shavings have been formed to a clear nest-creation, often mixed with fur

Figure 4. Doe fur scores. Upper left: 3 (poor fur), upper right: 2 (major plucking), lower left: 1 (minor plucking), lower right: 0 (full fur).

8.1.5 Maternal willingness

All does that had kits were observed during 4 of the mornings when the hatches were opened, the first 10 days post-parturition. The does position was recorded before the hatch was opened (nose against hatch, close to hatch, or far from hatch), if the doe was scratching the wall against the nest (yes/no), when the hatch was opened (the doe entered the nest voluntarily, the doe had to be nudged by an observer, or the doe had to be carried into the nest) (Table 6). The observer was checking if the doe had left the nest by herself after nursing, i.e. 7mins after the hatch was opened (yes/no).

Table 6. Ethogram for maternal behaviour

Doe position before opening of the hatch	
Nose close	Doe stands or sits ready to enter the nest-box with her nose against the hatch
Close	Doe stands or sits in the front half of the cage
Far	Doe stands, sits, or lays in the back half of the cage
Scratching	Doe scratches the hatch
Maternal willingness after opening of the hatch	
By herself	Doe goes in to the cage by herself
With hand	Doe has to be nudged with a human hand to go in to the cage
Carried	The hatch has to be closed and the doe carried into the nest by a human
Leave nestbox after nursing	
Out in 7mins	Doe leaves the nest-box within seven minutes
No recording	
No kits	Doe has not kindled
Cage opened	Doe has opened the cage by herself and has already given milk to the kits

8.1.6 The mothers' reaction to the manipulation of progeny by human

All does that had kits were observed while their kits were taken away from them and put in the nest where the hatch was closed (Table 7). The behaviour of the doe was recorded before (initial position and number of kits with the doe in the cage or in the nest), when all kits were removed (calm, fearful, scratching, curious, worried, approaches, or retires), and after the hatch was reopened and the doe regained contact with the kits (calm, fear, curious, approach, sniff kits, or retires). If the doe remained immobile during the entire test this was also recorded.

Table 7. Ethogram for the mothers' reaction to the manipulation of progeny by human

Before test (only when hatch is opened)	
Doe position	Standing (all paws to the ground, the rump and chest lifted from the ground)
	Not standing
% of kits	Percentage of kits in the cage with the doe
Doe reaction to the manipulation of kits	
Freeze	Doe freezes, fearful expression in the eyes
Back away	Doe moves to the back of the cage
Calm	Doe is calm and shows no particular reaction
Approach	Doe approaches the opening of the cage
Curiosity	Doe approaches the opening of the cage exploring, may stand on her back-paws
Scratching	Doe scratches the hatch
Doe reaction when reunited with kits	
Freeze	Doe freezes, fearful expression in the eyes
Back away	Doe moves to the back of the cage
Calm	Doe is calm and shows no particular reaction
Approach	Doe approaches the opening of the cage
Curiosity	Doe approaches the opening of the cage exploring, may stand on her back-paws
Sniff kits	Doe sniffs the kits

8.2 Statistical analyses

Statistical analyses were conducted in R (2013) where descriptive statistics and ANOVA were conducted and the “lsmeans” package (Russel, 2014) was used to find least square means. ANOVA was used to compare the variations in means between the different behavioural groups. The descriptive statistics were assessed in order to compare the two kit batches as accurately as possible as well as compare the two species in a clear way. ANOVA was conducted with the following models to see if certain behaviours had an effect on the litter growths, dam weight differences and survival.

Does:

1) Doe weight difference d12-26 = behavioural trait + litter size + health score + residual
2) Doe weight difference d26-33 = behavioural trait + litter size + health score + residual
3) Doe weight difference d12-33 = behavioural trait + litter size + health score + residual
4) Litter growth d4-11 = behavioural trait + litter size + health score + residual
5) Litter growth d11-34 = behavioural trait + litter size + health score + residual
6) Litter growth d4-34 = behavioural trait + litter size + health score + residual
7) Kit mortality % = behavioural trait + litter size + health score + residual

The models were determined by the effects that were available, therefore each behavioural effect that was tested in does was corrected for litter size and health score. Health score was included in the model because it was initially thought to have an effect on the performance, or the lack of the performance, of certain behaviours. Parity number was not included in the analysis since it was considered to not have any significant effects in upper parities. Only does with kits were observed and analysed, except for in the avoidance test where all does were observed. Lsmeans (Russel, 2014) package was used to get the least square means for these weight- and survival variables. The results presented hereafter are the ones that showed to be statistically significant in the litter growth of kits in both batches. Results where a low prevalence of the behaviour was seen are not presented.

9. RESULTS

Numerous measurements and analyses were made on both sow and doe data since the initial belief was that there would be few or no significant differences between groups in the doe data. Due to the large amount of significant results that were found, the results part has been narrowed down to the most interesting ones. The results from the sow data analyses were considered to not be of equal importance as the doe data results and were thus excluded since significant results were found in does.

9.1 Descriptive statistics

There were different numbers of does in each weight category (weights and weight differences). It seemed does gained weight between d12-d26, but lost weight between d26-d34 (see figure 4). The means of the weights were numerically alike in batch 1 and batch 2 (Table 8). The differing number of does between batch 1 and 2 was due to a streptococcus infection that attained the experimental herd.

Table 8. Descriptive statistics of doe weights, litter weight and weight differences in batch 1 and 2.

Weight	*N*	*mean*	*Std*	*min*	*max*	*N*	*mean*	*Std*	*min*	*max*
	Batch 1					Batch 2				
Doe weight d12	95	4389	370	3317	5755	79	4460	329	3745	5635
Doe weight d26	96	4763	392	3618	5650	83	4770	429	3168	5929
Doe weight d33	94	4576	432	2929	5319	83	4627	421	3185	5489
Doe wdiff. d12-26	94	383	307	-542	928	77	381	250	-167	855
Doe wdiff. d26-33	90	-191	216	-873	382	77	-156	239	-1412	221
Doe wdiff. d12-33	91	195	336	-748	718	77	225	323	-1048	777
Litter weight d4	79	810	122	524	1081	63	854	127	593	1167
Litter weight d11	79	1801	214	1328	2157	62	1834	221	1286	2333
Litter weight d34	79	7026	672	4926	8119	63	7535	682	5455	8993
Litter growth d4-11	67	1000	171	595	1446	62	972	171	561	1289
Litter growth d11-34	66	5286	433	3974	6029	62	5696	522	4069	6902
Litter growth d4-34	66	6286	536	4867	7144	63	6681	627	4694	8038

There were different numbers of litters in batch 1 and 2 (Table 9). The average number of kits born/litter, stillborn kits, and litter size at d4 were alike in both batches. Only the number of dead kits/litter during the first week of lactation (and therefore also the percentage) was higher in batch 2 than in batch 1.

Table 9. Descriptive statistics of survival rate of kits and litter size in period 1 and 2.

	N	*mean*	*Std*	*min*	*max*	*N*	*mean*	*Std*	*min*	*max*
			1					2		
Litter size d0 total born	81	10.1	3.5	2	19	61	10.8	1.7	7	18
Number stillborn kits	81	0.6	1.8	0	14	61	0.6	1.6	0	10
Litter size d4 after cross fostering	81	9.9	1.2	8	14	61	9.6	0.9	6	11
Number of dead kits/litter d4-d10	49	1.4	0.9	1	5	61	1.4	1.7	0	9
% of dead kits/litter d4-d10	81	7.6%	10.3%	0%	55%	61	11 %	11%	0 %	50 %

Does were weighed 3 times during each batch. In figure 4, the weight curve of the does is presented. Overall, the does gained weight between the AI d12 and the weighing d26, but lost weight between d26 and weaning (blue line). Does with kits in both batches gained weight, lost it, and regained it during lactation. However, does with kits in the first batch only, did not regain weight during the second batch. Does with kits in the second batch only, gained weight batch 2, but not as much during batch 1.

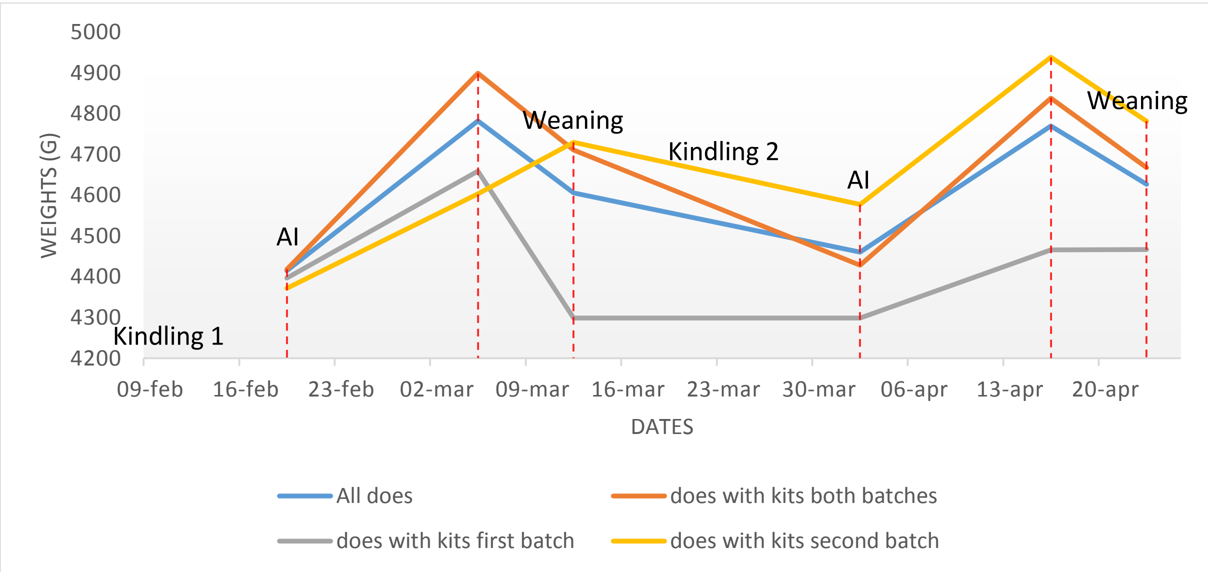

Figure 4. Timeline of doe weights over batch 1 and batch 2.

9.2 Behavioural statistics

Does that entered the nest by themselves had larger litter growths between day 4 and 11, especially in batch 2 (Table 10). Does that entered the nest by themselves had higher litter growths from birth to weaning, especially in batch 2 (Table 11). Agitated does during handling day 33 had higher litter weight gains in both batches. Passive does after handling on day 33 had larger litter growths than active ones. Does with the nose close to the hatch day 4 had a higher litter growth between day 11 and weaning in both batches, especially in batch 2 (Table 12). The does that were agitated during, and confident after, handling day 26 had on average higher litter weight gains. Passive does after handling had higher litter weight gains than active ones on day 12 and day 33. Does with poor fur (the most plucked fur) had a larger litter growths in all three litter growth variables. The does with full fur had the smallest litter growths (Table 13).

Table 10. Significant results concerning the litter growth between d4-d11

Beh trait class	*N*	*Raw means (g)*	*LS means (g)*	*Beh trait p-value*	*Contrast*	*Contrast µ ± SE (g)*	*Litter size p-value*	*Health p-value*
				Litter growth d4-11				
Maternal willingness d4, b1				n.s.	-	-	0.002	n.s.
1, By herself	64	982	981					
2, With hand	0	-	-					
3, Carried in nest	6	1007	973					
Maternal willingness d4, b2				0.10	1 – 3	83 ± 47	0.0003	n.s.
1, By herself	41	994	992					
2, With hand	0	-	-					
3, Carried in nest	18	912	909					

Table 11. Significant results concerning the litter growth between d4-d34

Beh trait class	*N*	*Raw means (g)*	*LS means (g)*	*Beh trait p-value*	*Contrast*	*Contrast µ ± SE (g)*	*Litter size p-value*	*Health p-value*
				Litter growth d4-34				
Maternal willingness d4, b1				n.s.	-	-	1.46e-07	n.s.
1, By herself	63	6275	6189					
2, With hand	0	-	-					
3, Carried in nest	6	6097	5925					
Maternal willingness d4, b2				0.04	1 – 3	297 ± 172	1.86e-11	n.s.
1, By herself	41	6733	6717					
2, With hand	0	-	-					
3, Carried in nest	18	6441	6420					
Beh. during handling, d33, b1				n.s.	-	-	1.97e-08	n.s.
0, Calm	51	6240	6126					
1, Agitated	23	6389	6306					
Beh. during handling, d33, b2				0.08	0 – 1	-426 ± 169	1.21e-12	n.s.
0, Calm	54	6620	6025					
1, Agitated	9	7050	6451					
After handling, d33, b1				0.007	0 – 1	-259 ± 100	1.19e-08	n.s.
0, Active	32	6145	6057					
1, Passive	40	6407	6316					
After handling, d33, b2				n.s.	-	-	5.91e-12	n.s.
0, Active	21	6616	6029					
1, Passive	42	6714	6084					

Table 12. Significant results concerning the litter growth between d11-d34

Beh trait class	*N*	*Raw means (g)*	*LS means (g)*	*Beh trait p-value*	*Contrast*	*Contrast μ ± SE (g)*	*Litter size p-value*	*Health p-value*
				Litter growth d11-34				
Mat. Beh. Doe position d4, b1				n.s.	-	-	3.08e-07	n.s.
1, Scratching	18	5205	5115					
2, Nose close	37	5335	5274					
3, Close	6	4840	4806					
4, Far	8	5413	5234					
Mat. Beh. Doe position d4, b2				0.02	-	-	1.24e-10	n.s.
1, Scratching	0	-	-					
2, Nose close	47	5725	5716					
3, Close	6	5410	5429					
4, Far	5	5392	5397					
Beh. during handling, d26, b1				n.s.	-	-	5.9e-08	n.s.
0, Calm	52	5282	5205					
1, Agitated	22	5297	5168					
Beh. during handling, d26, b2				0.07	-	-	1.8e-11	n.s.
0, Calm	46	5638	5171					
1, Agitated	18	5836	5148					
After handling, d12, b1				0.08	-	-	1.25e-07	n.s.
0, Active	44	5227	5172					
1, Passive	30	5373	5228					
After handling, d12, b2				n.s.	-	-	1.94e-11	n.s.
0, Active	22	5712	5189					
1, Passive	40	5686	5203					
After handling, d33, b1				0.06	0 – 1	-146 ± 83	4.85e-08	n.s.
0, Active	34	5209	5135					
1, Passive	40	5352	5281					
After handling, d33, b2				n.s.	-	-	1.43e-11	n.s.
0, Active	21	5633	5184					
1, Passive	41	5728	5248					
After handling, d26, b1				n.s.	-	-	3.26e-08	n.s.
0, Fearful	51	5258	5161					
1, Confident	23	5350	5277					
After handling, d26, b2				0.03	-	-	1.83e-11	n.s.
0, Fearful	44	5631	5153					
1, Confident	18	5852	5226					

Table 13. Significant results concerning fur scores

Wegiht diff.	*Fur score*	*N*	*Raw means*	*LS means*	*Beh trait p-value*	*Contrast*	*Contrast μ ± SE*	*Litter size p-value*	*Health p-value*
Litter growth d4-11	*Fur score, d5, b2*				0.005	0 – 1	-141 ± 49	2.25e-05	n.s.
	0, Full fur	17	868	762		0 – 2	-159 ± 56		
	1, Slightly plucked	25	1004	903		0 – 3	-202 ± 71		
	2, Plucked	13	997	921					
	3, Poor fur	7	1071	964					
Litter growth d11-34	*Fur score, d5, b2*				0.02	0 – 1	-353 ± 117	4.24e-12	n.s.
	0, Full fur	17	5426	5003		0 – 2	-482 ± 169		
	1, Slightly plucked	25	5862	5357					
	2, Plucked	13	5577	5210					
	3, Poor fur	7	5973	5486					
Litter growth d4-34	*Fur score, d5, b2*				0.003	0 – 2	-367 ± 150	3.56e-13	n.s.
	0, Full fur	17	6295	5764		0 – 3	-686 ± 190		
	1, Slightly plucked	25	6893	6265					
	2, Plucked	13	6574	6131					
	3, Poor fur	7	7044	6450					

9.3 Frequency of maternal behaviour

Frequency and combinations of behaviours was studied in the doe behaviours after human handling and in the fur scores. The most common behaviour combination after handling was calm, active and confident, and calm, passive and confident in all 3 days in both batches (Table 14-16). The most common combination of fur scores was that a score 1 often followed another score 1 (Table 17).

Table 14. After weighing matrix d12

Beh.	Nervous	Calm
Active	Fearful: 2 Confident: 4	Fearful: 5 Confident: 46
Passive	Fearful: 14 Confident: 12	Fearful: 3 Confident: 22

Table 15. After weighing matrix d26

Beh.	Nervous	Calm
Active	Fearful: 9 Confident: 20	Fearful: 3 Confident: 34
Passive	Fearful: 7 Confident: 6	Fearful: 1 Confident: 28

Table 16. After weighing matrix d33

Beh.	Nervous	Calm
Active	Fearful: 10 Confident: 7	Fearful: 4 Confident: 36
Passive	Fearful: 12 Confident: 8	Fearful: 5 Confident: 26

Table 17. Fur score matrix

		27-mar			
		0	1	2	3
	0	9	1	1	0
23-apr	1	8	13	3	1
	2	0	7	4	3
	3	0	4	6	3

Table 18. Nest building matrix of batch 1 and 2

	batch 1	batch 2
No nest	27	19
Small nest	21	23
Big nest	7	13

Table 19. Matrix of the reaction at opening of the cage in batch 1 and 2

	batch 1, d0	batch 1, d6	batch 2, d0	batch 2, d6
Freeze	8	12	0	0
Back away	11	7	21	14
Calm	67	37	52	57
Curious	0	30	13	15

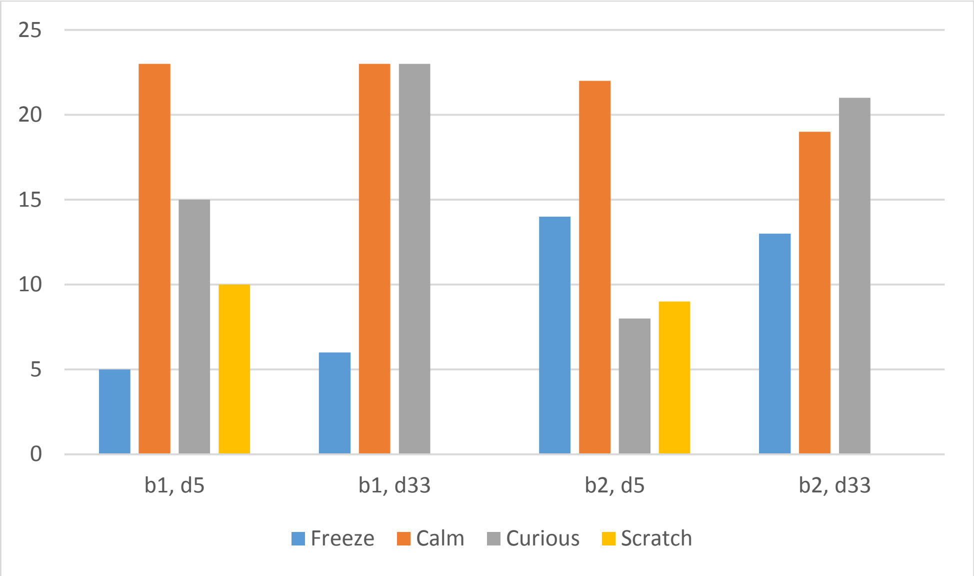

Figure 5. Frequency of doe reaction to the handling of kits.

Does built more nests in the second batch than in the first (Table 18). The most common reaction in the human avoidance test when opening the cage was to be calm in both batches (Table 19). Backing away was more common in batch 2 than in batch 1, however, in batch one does performed freezing behaviour, which was not present in batch 2. During human handling of kits being calm or curious was most common (Figure 5). In the second batch freezing was more common than in the first. Scratching only occurred day 5 in both batches because the hatch was still closed at that point. The does generally went in to the nests by themselves during maternal willingness observations of batch 1 and 2 (Table 20).

Table 20. Matrix of maternal willingness to enter the nest batch 1 and 2

	batch 1, d3	batch 1, d4	batch 1, d5	batch 1, d11	batch 2, d3	batch 2, d4	batch 2, d5	batch 2, d11
By herself	36	37	38	30	33	29	32	34
Touched	4	0	0	2	2	0	0	2
Carried	0	3	2	6	6	11	8	4

10. DISCUSSION

The overall aim of this project was to study a potential relationship between maternal behaviour and the growth and survival of progenies of sows and does. The main idea of this appeared when looking into ways in which the production of these animals could be enhanced as to increase the wellbeing of the animals whilst improving productivity. As it looks today, even though maternal abilities such as litter size and milk production are selected on, the number of weaned kits per doe is not necessarily higher since the mortality rate increases with higher litter sizes (Poigner *et al.* 2000). This is presumably because the doe lacks of resources to cope with a larger litter. Therefore, when searching upon other alternatives to increase survival and growth, maternal behaviour studies showed to be interesting. What if a doe expressing more maternal behaviour is more capable of handling a faster growing litter than one that expresses less? In order to answer this question, other questions such as; what is good doe maternal behaviour? And; is a high level of expression of maternal behaviour necessarily advantageous for the doe and kits?

Since these ideas and questions are unexplored in the world of rabbit husbandry, the pig was brought in as a model animal, where maternal behaviour studies are slightly more established, in order to gain more knowledge in the field and ultimately increase the chances of obtaining significant results. However, since a surprising amount of significant results were found when analysing the rabbit data alone, the results concerning the pig data in this project report were excluded. The hypothesis of the study, that does show variation in maternal behaviour and that some behaviours are more beneficial for litter growth than others, was determined in an early stage of this this project. The more precise behavioural hypotheses (i.e. high maternal willingness, calmness, agitation during handling, passivity after handling and high level of fur plucking) were determined in a later stage, when some behavioural observations had been carried out and some early tendencies could be perceived.

Surprisingly, significant results were found to a point that even the rabbit results had to be narrowed down to the most interesting findings, which turned out to be doe maternal behaviour possibly affecting kit growth between birth and weaning.

10.1 Methodology

The behavioural and technical protocol which were used for this project are the first of their kind. Therefore, in order to gain the most out of them, some changes were made during the course of the observations. Some of these changes may, or may not, have had an effect on the final results, which is why they are discussed hereafter.

Changes that were made in the protocol were for instance; adding a level (curiosity) in the human avoidance test (Table 3), two levels of agitation (agitated and very agitated) in the behaviour at handling (Table 4) and the “doe reaction when reunited with kits” part in the mothers’ reaction to the manipulation of progeny by human (Table 7). While some observational levels were added, others were excluded (such as stomping during avoidance test or very agitated during handling) due to that the frequency of performance was too low. The observations of doe behaviour at handling were carried out during weighing of the does according to regular farm protocols so as to not expose the does to more handling than necessary. The "before handling" step in the protocol was the most difficult to record since there was only a subtle difference between the calm and the freezing behaviour. Hence, this behaviour was removed from the results. Maternal behaviour (Table 6) was recorded at the opening of the hatch for the morning nursing the first 3 days after kindling and the last day the hatch was opened by a stockperson for that kit batch. The behaviour was however recorded in a total of five days since kindling occurred over 48 h. Thus, 3 days after kindling was considered to be on Monday for does kindling on Friday and on Tuesday for does kindling on Saturday. Day 4 was however considered to be on Wednesday for the entire herd (since kindling on Saturday was the most common). As nests were recorded, the prevalence of no nest was the highest (Table 5). However, there were two types of behaviour under the category of no nest; no nest was built or nest box used for urinating and defecating. Unfortunately, no difference was made in recording between these two types. The fur score was added to the second batch because this was found to be interesting during the first batch.

The number of does varied between the first and the second kit batch (Table 8) because of a streptococcus infection that attained the herd during the second batch. Thus, the conditions in the two batches were not entirely equal. Additionally, adoptions were carried out in the doe litters as to equalize litter sizes. Despite this, litter sizes varied between 8-14 kits in batch 1 and 6-11 in batch 2 due to pre-weaning mortality. With variable litter sizes, litter growth are affected and mothers may therefore differ in body resource mobilisation (Pascual *et al.* 2013; Gilbert *et al.* 2012). Does were weighed at 3 occurrences where the sanitary states of the does were also recorded. The most common sanitary state was minor or major paw damage. If this was detected the does were immediately treated with antiseptic spray. Kits were also weighed at 3 occurrences. If a kit was considered too weak, cold or sick, it was immediately removed from the litter. All dead kits were weighed, but no further use of these weights were found and thus no analyses were performed on these variables.

Initially, it was thought that the differences between cages would bias the results, since there were two cage types (Extrona and Chabeauti) (Figure 3) but no such bias could be found. The cages differed slightly in construction, with Extrona cages having nest hatches more easily opened by the does than the Chabeauti ones. This is one of the explanations for the higher prevalence of missing values in the maternal behaviour observation, since some does could choose when to nurse their kits.

There is a risk that some effects show to be significant by chance since numerous relationships have been analysed. The results that were chosen for this project report are the ones that showed to be statistically significant for kit litter growth, and therefore were considered to be of greatest interest.

10.2 Hypothesis and result

Since the herd was affected of a streptococcus infection, there was a total loss of 13 does between the batches, and thus the number of litters differed between batch 1 (N = 81) and 2 (N = 66) (Table 9). However, the infection did not seem to affect the number of born litters, since the descriptive statistics (i.e. number of stillborn kits and litter size day 4) show no major difference between batches. Only the number of dead kits between day 4 and 10 show an increase of almost 50 % in batch 2 (Table 9). In this project, weight differences were used in the analyses, as opposed to weights, due to that the body weight change was of grater interest than the actual weights of litters.

In accordance to Pascual *et al.* (2013) does gained weight between day 12 (AI) and day 26 (cv: 80 % batch 1, 66 % batch 2) and lost weight between day 26 and day 33 (cv: 113 % batch 1, 153 % batch 2) (Table 8). This indicates that the investment of body resources is highest at kindling, and lowest at day 26, approximately at the lactation peak of the doe (Figure 4). Logically, does that failed to have kits in the first batch had the lowest mean weights at weighing day 26, batch 1, since no milk production is needed from these does. Conversely, the does that failed to have kits in the second batch had the lowest mean weights day 26, batch 2, presumably for the same reason. However, how the effect of this body investment improves litter growth needs further research.

The rabbits in this project were fairly domesticated, with an overall low fear of human. This may be a result from early, and rather often, handling of kits from birth to weaning and, if kept in production, adult rabbits as well. According to Bilkó and Altbäcker (2000) reproductive performances of does are improved if they are handled as kits. A reason for this might be that the level of fear of human is decreased with early handling (Csatádi *et al.* 2005), and that the environment thus is less stressful for the animals, leading to more successful reproductive performances. This is in accordance with Bilkó and Altbäcker (2000) who state that a low fear of human is correlated with high reproductive performances.

Mother-young contact at parturition and in early lactation is of high importance for the expression of maternal behaviour of does (González-Mariscal *et al.* 1998), and thus also for litter growth. Litter growths day 4-11 and 4-34 were larger in does that had higher maternal willingness i.e. entered the nest by themselves by opening day 4, than the ones that were carried in both batches (Tables 10 and 11). Decreased health status was initially believed to be the main reason for being carried into the nest as opposed to going in by themselves, but health status was not found to be a significant factor in the subsequent analyses. Does standing with the nose close to the nest hatch on day 4 had higher litter growths day 11-34 than the ones that were close or far (Table 12). This indicates that does that are more prone to go in to nurse their kits have a higher litter growth than less prone ones. Avoidance of human may be a reason for not being prone to enter the nest. Does that went to the back of the cage at the arrival of the stockperson typically had to be carried inside the nest. If the stockperson went away, the doe would wait a moment before entering, but then finally enter. Thus, it is possible that these does are more stressed when surrounded by humans which may lead to a stressed nursing (i.e. not reaching its full capacity if disrupted due to human avoidance) finally leading to a litter growing more slowly.

Litter growth day 11-34 was higher in does that were calm during handling on day 26, passive instead of active after handling both day 12 and 33, and confident instead of fearful after handling day 26 (Table 12). This once again indicates that a low avoidance, and thus fear, of human decreases the stress that the handling may cause the does, leading to higher litter growths. Does that were passive after handling day 33 had higher litter growths from birth to weaning and from day 11-34. However, the litter weight from birth to weaning was higher in does that were agitated instead of calm during handling day 33 in both batches (Table 11). The agitation at handling day 33 is difficult to interpret. Perhaps the doe is protective of the kits and is thus more agitated, or perhaps the overall temper of the doe is worse than during the other handlings since the kits have grown big, leading to a substantial space reduction in the cage, an increase of activity in the cage, all while being pregnant.

Throughout all litter growths, poor fur does (does plucking the most fur) had higher litter growths than the does with other fur scores day 5 (Table 13). This indicates that the does plucking the most fur had the highest litter growths. Thus, there were differences in maternal investment which affected progeny growth.

The overall aim of this project was to study a potential relationship between maternal behaviour and the growth and survival of the progeny of sows and does, which was then narrowed down to doe maternal behaviour affecting litter growth between birth and weaning. Since no previous behavioural studies have, to the authors' knowledge, been done and compared to doe and litter growth rates this is going to be a first assumption of what determines advantageous maternal behaviour in does. Does spending a lot of energy on their progeny lose weight (Pascual *et al.* 2013) and thus have to regain it again for next litter, therefore good maternal abilities could be defined by a large weight difference during a kit batch. Being calm, passive and confident were the overall advantageous behaviours for higher litter growths, which can be considered as logic since the does are domesticated and fairly used to being handled. The fact that litter weights from birth to weaning were higher in does that were agitated instead of calm during handling day 33 in both batches may possibly be explained by does potentially being protective of their kits or have a slightly reduced overall state, thus protesting to handling at weighing.

10.3 Frequency

The most common combination of behaviours after handling were calm, active and confident, and calm, passive and confident (Table 14-16). Active behaviours vary from cage leaps to eating and drinking, whilst passive behaviour is mostly just calmly lying down instantly after being put back in the cage. These behaviours are considered equal on a calm-scale, leading to an unobvious difference between them. Passive behaviour did however show to have a favourable impact on litter growth, which would hence be the actual difference between them.

At a first view at the most common frequency of fur score it is evident that does having score 1 the 27th of March, also had score 1 the 23rd of April (N = 13) (Table 17). Then came having a score 0 followed by a score 0, and then a score 0 followed by a score 1. In other words, the fur score stays more or less the same during the whole period of a kit batch. However, one can also interpret the fur score matrix as fur score drops between the 27th of March and the 23rd of April. In this case there are 25 fur score drops (from 0 to 1 = 8, from 1 to 2 = 7, from 1 to 3 = 4, and from 2 to 3 = 6) indicating that the most common is to pluck fur during the course of a kit batch presumably to prepare for the parturition of the following batch.

In the first batch, the most common behaviour was to not build a nest (N = 27), whereas it was to build a small nest in batch 2 (N = 23) (Table 18). The expectation was to observe more big nests, and that does building larger nests would have a higher litter growth, but this was apparently not the case. Perhaps the behaviour is supressed in a production environment, as opposed to in nature, possibly stressing the animal, or it is simply not needed in a production environment with fairly regulated temperatures and conditions, and is thus only showing in does which have kept their natural instincts. The behaviour may simply not be crucial for survival anymore and has therefore lost in frequency of appearance. This theory is supported by González-Mariscal *et al.* (1988) who state that multiparous does do not need to build a nest prior to nursing in order to maintain their maternal responsiveness.

In opening of the cage in the avoidance test, calm was once again the most common behaviour in all four observations. The prevalence of calm behaviour was the highest in all days (Table 19), especially in day 1, batch 1, but this is however probably because the curious category was added to the protocol only on day 6 of the first batch. Thus, in the calm category of batch 1, day 0, both calm and curious are included. This clearly shows that most does were calm during the observations, and that they therefore are fairly used to be in daily contact with human handlers.

Calm and curious does were the most common ones in doe reaction to the handling of kits (Figure 5). Scratching was only recorded in day 5 in both batches since the hatch was still closed during day five. There was however a possibility for the scratching behaviour to be recorded in day 33 also, since the hatch was closed by the handler that took all the kits and put them in the nest, but the behaviour was nonetheless not recorded. This also shows that the does felt a certain level of trust towards humans, since they did not show any aggressive or protective behaviour.

In the maternal willingness repeatability, going in to the nest by themselves was the most common behaviour (Table 20). This indicates that most does in this experimental herd feel an urge to nurse their kits.

10.4 Possible future implementations

First of all, were the questions asked above answered? Is a doe who is expressing more maternal behaviour more capable of handling a faster growing litter than one that expresses less? And the answer is yes, judging from the results of this project, at least when considering maternal willingness and fur plucking, since does more prone to enter the nest and does entering by themselves, have higher litter growths, as do does that pluck more fur.

The next questions were; what is good doe maternal behaviour? And; is a high level of expression of maternal behaviour necessarily advantageous for the doe and kits? This is still hard to say. It can for instance be seen that drastic weight changes during lactation increases the growth of the litter. It is however not known, whether this is good for the doe or not. The doe may be resource allocating in the most successful way, keeping a sufficient amount of energy whilst giving the necessary amount to the kits as to increase their growth, or, a doe may be resource allocating in a disadvantageous way for the doe, ending up with too little energy and therefore suffering. The same thing can be seen in fur plucking. Does plucking a lot of fur have higher litter growths, but how is this affecting the does is unclear. The doe will need to increase its daily feed intake in order to stay warm, and once again risk to be exposed to suffering.

Then there is the avoidance of human aspect; judging from the results of this project, does that are less avoiding towards humans, and thus feel less stressed in a production environment, show an increase in prevalence of maternal behaviour. These are clearly only speculations which need further research in order to be confirmed. But nonetheless, relations between maternal behaviour and litter growth in does have been found during this project. If subsequent studies would come to the same conclusions as in this project, including maternal behaviour in breeding programmes could possibly and eventually increase the welfare, survival and growth of the kits. This would then possibly lead to that the rabbit production would be further improved with increased inclusion of maternal behaviour in breeding programmes. However, further research will be needed in order to determine what good maternal behaviour in rabbit is, or which level of maternal behaviour that is the most advantageous for both kits and does. Thus, no conclusions can to this day be drawn on whether it would be advantageous or not for production to breed on maternal behaviour.

11. CONCLUSION

The conclusion of this project is that behavioural differences in does, affecting litter growth between birth and weaning, were found. A high maternal willingness was found advantageous for litter growth. This indicates that does more prone to enter the nest box at nursing have a higher litter growth rate than less prone does. Calmness during handling in does was found advantageous for litter growth, presumably because the level of stress in these does is lower, leading to a higher welfare and thus a higher litter growth. Agitation during handling was found advantageous for litter growth in day 33 observations. Reasons for this might either be that the doe is protective of her kits, or perhaps that the overall temper of the doe is decreased due to the lack of space and increased activity in the cage with grown kits. Passivity after handling was also found advantageous for kit growth, possibly due to a low level of fear of human and therefore a less stressed environment. Finally, a high level of fur plucking was seen advantageous for the growth of the litter. However, it is not known how a high level of fur plucking affects the does’ overall health. Further research will thus be needed in order to study which maternal behaviours are good maternal behaviours, and what level of maternal behaviour that is the most advantageous for the doe and kits.

12. REFERENCES

Algers, B., Uvnäs-Moberg, K., 2007. Maternal behaviour in pigs. Hormones and Behaviour, 52 (2007) 78–85.

Algers, B., 1993. Nursing in pigs: Communicating needs and distributing resources. Journal of Animal Science, 71 (1993) 2826-2831.

Arey, D. S. & Sancha, E. S., 1996. Behaviour and productivity of sows and piglets in family system and in farrowing crates. Applied Animal Behaviour Science, 50 (1996) 135-145.

Baumann, P., Oester, H., Stauffacher, M., 2005a. Effects of temporary nest box removal on maternal behaviour and pup survival in caged rabbits (Oryctolagus cuniculus). Applied Animal Behaviour Science, 91 (2005) 167-178.

Baumann, P., Oester, H., Stauffacher, M., 2005b. The influence of pup odour on the nest related behaviour of rabbit does (Oryctolagus cuniculus). Applied Animal Behaviour Science, 93 (2005) 123-133.

Blackshaw, J. K., Blackshaw, A.W., Thomas, F. J., Newman, F. W., 1994. Comparison of behaviour patterns of sows and litters in a farrowing crate and a farrowing pen. Applied Animal Behaviour Science, 39 (1994) 281-295.

Blasco, A., Santacreu, M. A., Thompson, R., Haley, C. S., 1993. Estimates of genetic parameters for ovulation rate, prenatal survival and litter size in rabbits from an elliptical selection experiment. Livestock Production Science, 34 (1993) 163-174.

Bilkó, Á. & Altbäcker, V., 2000. Regular handling early in the nursing period eliminates fear responses toward human beings in wild and domestic rabbits. Developmental Psychobiology, 36 (2000) 78-87.

Bouquet, A., Delaunay, I., Merour, I., Bellec, T., Ligonesche, B., Sourdioux, M., Bidanel, J-P., Canario, L., 2014. Conséquences d'une sélection sur l'homogénéité du poids des porcelets à la naissance sur la productivité numérique des truies Large White et Landrace Français. Journées Recherche Porcine, 46 (2014) 19-24.

BPEX, British Pig Executive Yearbook 2012-2013. Industry statistics [Available 2014-02-21] http://www.bpex.org.uk/downloads/302959/302872/The%20BPEX%20Yearbook%202013%20-%20Industry%20Statistics.pdf

Canario, L., 2006. Aspects génétiques de la mortalité des porcelets à la naissance et en allaitement précoce : relations avec les aptitudes maternelles des truies et la vitalité des porcelets. Thèse de doctorat. Institut National d'Agronomie Paris-Grignon.

Coureaud, G., Fortun-Lamothe, L., Rödel, H.-G.,Monclús, R., Schaal, B., 2008. Le lapereau en dévelopment : donnés comportementales, alimentaires et sensorielles sur la période naissance-sevrage. INRA Productions Animales, 3, 21 (2008) 231-238.

Coureaud, G., Schaal, B., Coudert, P., Hudson, R., Rideaud, P., Orgeur, P., 2000. Mimicking natural nursing conditions promotes early pup survival in domestic rabbits. Ethology, 106 (2000) 207-225.

Cronin, G. M. & van Amerongen, G., 1991. The effects of modifying the farrowing environment on sow behaviour and survival and growth of piglets. Applied Animal Behaviour Science, 30 (1991) 287-298.

Cronin, G. M., Barnett, J. L., Hodge, F. M., Smith, J. A., McCallum, T. H., 1991. The welfare of pigs in two farrowing/lactation environments: cortisol responses of sows Applied Animal Behaviour Science, 32 (1991) 117-127.

Cronin, G. M. & Smith, J. A., 1991. Effects of accommodation type and straw bedding around parturition and during lactation on the behaviour of primiparous sows and survival and growth of piglets to weaning. Applied Animal Behaviour Science, 33 (1991) 191-208.

Crowell-Davis, S. L., 2007. Behavior problems in pet rabbits. Journal of Exotic Pet Medicine, 16 (2007) 38-44.

Csatádi, K., Bilkó, Á., Altbäcker, V., 2006. Specificity of early handling: Are rabbit pups able to distinguish between people? Applied Animal Behaviour Science, 107 (2006) 322-327.

Dal Bosco, A., Rebollar, P. G., Boiti, C., Zerani, M., Castellini, C., 2011. Ovulation induction in rabbit does: Current knowledge and perspective. Animal Reproduction Science, 129 (2011) 106-117.

Deutsch, J. A., 1957. Nest building behaviour of domestic rabbits under semi-natural conditions. The British Journal of Animal Behaviour, 5 (1957) 53-54.

Dúcs, A., Bilkó, Á., Altbäcker, V., 2009. Physical contact while handling is not necessary to reduce fearfulness in the rabbit. Applied, Animal Behaviour Science, 121 (2009) 51-54.

Dellmeier, G. R. & Friend, T. H., 1991. Behavior and extensive management of domestic sows (Sus scrofa) and litters. Applied Animal Behaviour Science, 29 (1991) 327-341.

Dyck, G.W. & Swierstra, E. E., 1987. Causes of piglet death from birth to weaning. Canadian Journal of Animal Science 67 (2) (1987) 543-547.

Drake, A., Fraser, D., Weary, D. M., 2008. Parent-offspring resource alloction in domestic pigs. Behaviour Ecology Sociobiology, 62 (2008) 309-319.

Fortun-Lamothe, L., Coureaud, G., Langlois, D., Schaal, B., 2007. La réactivité des lapereaux à la pheromone mammaire : un indicateur de viabilité? 12èmes Journées de la recherché cunicole, 27-28 novembre 2007, Le Mans, France.

Gilbert, H., Bidanel, J.-P., Billon, Y., Lagant, H., Guillouet, P., Sellier, P., Noblet, J., Hermesch, S., 2012. Correlated responses in sow appetite, residual feed intake, body composition, and reproduction after divergent selection for residuel feed intake in the growing pig. Jornal of Animal Science, 90 (2012) 1097-1108.

Gill, P., 2007. Managing reproduction – critical control points in exceeding 30 pigs per sow per year. London Swine Conference – Today's Challenges… Tomorrow's opportunities, 3-4 April, 2007. [Available 2014-02-25] www.londonswineconference.ca/proceedings/2007/LSC2007_PGill2.pdf

Gonzàlez-Mariscal, G., McNitt, J. I., Lukefahr, S. D., 2007. Maternal care of rabbits in the lab and on the farm: Endocrine regulation of behavior and productivity. Hormones and Behavior, 52 (2007) 86-91.

Gonzáles-Mariscal, G., Melo, A. I., Chirino, R., Jiménez, P., Beyer, C., 1998. Importance of mother/young contact at parturition and across lactation for the expression of maternal behaviour in rabbits. Developmental Psychobiology, 32, vol. 2, (1998) 101-111.

Grandinson, K., Lund, M. S., Rydhmer, L., Strandberg, E., 2010. Genetic parameters for the piglet mortality traits crushing, stillbirth and total mortality and their relation to birth weight. Acta Agriculturae Scandinavica, Section A – Animal Science 52:4 167-173.

Grandinson, K., Rydhmer, L., Strandberg, E., Thodberg, K., 2003. Genetic analysis of on-farm tests of maternal behaviour in sows. Livestock Production Science, 83 (2003) 141–151.

Gäde, S., Bennewitz, J., Kirchner, K., Looft, H., Knap, P. W., Thaller, G., Kalm, E., 2008. Genetic parameters for maternal behaviour traits in sows. Livestock Science, 114 (2008) 31-41.

Heape, W., 1905. Ovulation and degeneration of ova in the rabbit. Proceedings of the Royal Society Lond. B, vol 76, no. 509 (1905) 260-268.

Hemsworth, P. H. and Barnett, J. L., 2000. The biology of animal stress: basic principles and implications for animal welfare/ edited by G.P. Moberg and J.A. Mench. ISBN 0-85199-359-1. First printed 2000, reprinted 2001.

Hemsworth, P. H., Barnett, J. L., Coleman, G. J., Hansen, C., 1989. A study of the relationships between the attitudinal and behavioural profiles of stockpersons and the level of fear of humans and reproductive performance of commercial pigs. Applied Animal Behaviour Science, 23 (1989) 301-314.

Heim, G., Mellagi, A. P. G., Bierhals, T., de Souza, L. P., de Fries, H. C. C., Piuco, P., Seidel, E., Bernardi, M. L., Wentz, I., Bortolozzo, F. P., 2012. Effects of cross-fostering within 24 h after birth on pre-weaning behaviour, growth performance and survival rate of biological and adopted piglets. Livestock Science, 150 (2012) 121-127.

Hoy, S. & Selzer, D., Frequency and time of nursing in wild and domestic rabbits housed outdoors in free range (2002). World Rabbit Science, vol. 10 (2002) 77-84.

Isberg, S., 2013. Management factors influencing sow productivity in successful Swedish and Danish herds. Epsilon publication, SLU [Available 2014-02-21]http://stud.epsilon.slu.se/5327/7/isberg_s_130228.pdf

Janczak, A. M., Pedersen, L. J., Rydhmer, L.., Makken, M., 2003. Relation between early fear- and anxiety-related behaviour and maternal ability in sows. Applied Animal Behaviour Science, 82 (2003) 121-135.

Jensen, P., 1988. Maternal behaviour and mother-young interactions during lactation in free-ranging domestic pigs. Applied Animal Behaviour Science, 20 (1988) 297-30.

Jensen, P., 1986. Observations on the maternal behaviour of free-ranging domestic pigs. Applied Animal Behaviour Science, 16 (1986) 131-142.

Jezierski, T. A. & Konecka, A. M., 1996. Handling and rearing results in young rabbits. Applied Animal Behaviour Science, 46 (1996) 243-250.

KilBride, A. L., Mendl, M., Statham, P., Held, S., Harris, M., Cooper, S., Green, L. E., 2012. A cohort study of preweaning piglet mortality and farrowing accommodation on 112 commercial pig farms in England. Preventive Veterinary Medicine, 104 (2012) 281-291.

Laws, J., Amusquivar, E., Laws, A., Herrera, H., Lean, I. J., Dodds, P. F., Clarke, L., 2009. Supplementation of sow diets with oil during gestation: Sow body condition, milk yield and milk composition. Livestock Science, 123 (2009) 88-96.

Lebas, F., Coudert, P., de Rochambeau, H., Thébault, R.G., 1997. The Rabbit: Husbandry health and reproduction. FAO Animal Production and Health Series, No. 21, ISSN 1010-9021, ISBN: 92-5-103441-9.

Løvendahl, P., Holm Damgaard, L., Lindstrøm Nielsen, B., Thodberg, K., Su, G., Rydhmer, L., 2005. Aggressive behaviour of sows at mixing and maternal behaviour are heritable and genetically correlated traits. Livestock Production Science, 93 (2005) 73-85.

Maertens, L., Lebas, F., Szendrö., Zs., 2006. Rabbit milk: a review of quantity, quality and non-dietary affecting factors. World Rabbit Science, 14 (2006) 205-230.

Martínez-Gómez, M., Juárez, M., Distel, H., Hudson, R., 2004. Overlapping litters and reproductive performance in the domestic rabbit. Physiology & Behaviour, 82 (2004) 629-636.

Milligan, B. N., Fraser, D., Kramer, D. L., 2002. Within-litter birth weight variation in the domestic pig and its relation to pre-weaning survival, weight gain, and variation in weaning weights. Livestock Production Science, 76 (2002) 181-191.

Moreki, J. C., 2007. Commercial rabbit production. Rabbits today, RAB 01, June 2007.

Mugnai, C., Dal Bosco, A., Castellini, C., 2009. Effect of different rearing systems and pre-kindling handling on behaviour and performance of rabbit does. Applied Animal Behaviour Science, 118 (2009) 91-100.

Pascual, J, J., Savietto, D., Cervera, C., Baselga, M., 2013. Resource allocation in reproductive rabbit does: A review of feeding and genetic strategies for suitable performance. World Rabbit Science, 21 (2013) 123-144.

Pedersen, L. J., Malmkvist, J., Andersen, H. M. L., 2013. Housing of sows during farrowing: a review on pen design, welfare and productivity. Livestock housing: modern management to ensure optimal health and welfare of farm animals, Wageningen Academic Publishers 2013.

Pigwin, medeltal slaktgris, [Available: 2014-06-01] http://www.pigwin.se/ovrigt-4/medeltal-2011/medeltal-slakt

Poigner, J., Szendrõ, Z., Lévai, A., Radnai, I., Biró-Németh, E., 2000. Effect of birth weight and litter size on growth and mortality in rabbits. World Rabbit Science, 8 (2000) 17-22.

R Core Team (2013). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/

Rashwan, A. A. & Marai, I. F. M., 2000. Mortality in young rabbits: A review. World Rabbit Science, 8 (2000) 111-124.

Russell V. Lenth (2014). lsmeans: Least-Squares Means. R package version 2.00-5. http://CRAN.R-project.org/package=lsmeans

Rödel, H. G., Prager, G., Stefanski, V., von Holst, D., Hudson, R., 2008. Separating maternal and litter-size effects on early postnatal growth in two species of altricial small mammals. Physiology & Behaviour 93 (2008) 826-834.

Scott, K., Laws, D. M., Courboulay, V., Meunier-Salaün, M-C., Edwards, S. A., 2009. Comparison of methods to assess fear of humans in sows. Applied Animal Behaviour Science, 118 (2009) 36-41.

Selzer, D., Lange, K., Hoy, St., 2004. Frequency of nursing in domestic rabbits under different housing conditions. Applied Animal Behaviour Science, 87 (2004) 317-324.

Šilerová, J., Špinka, M., Šárová, R., Slámová, K., Algers, B., 2006. A note on differences in nursing behaviour on pig farms employing individual and group housing of lactating sows. Applied Animal Behaviour Science, 101 (2006) 167-176.

Špinka, M., 2006. How important is natural behaviour in animal farming systems? Applied Animal Behaviour Science, 100 (2006) 117-128.

Stewart, K.R., Flowers, W.L., Rampacek, G.B., Greger, D.L., Swanson, M. E., Hafs, H.D., 2010. Endocrine, ovulatory and reproductive characteristics of sows treated with an intravaginal GnRH agonist. Animal Reproduction Science, 120 (2010) 112-119.

Valros, A., Rundgren, M., Špinka, M., Saloniemi, H., Hultén, F., Uvnäs-Moberg, K., Tománek, M., Krejcí, P., Algers, B., 2004. Oxytocin, prolactin and somatostatin in lactating sows: association with mobilisation of body resources and maternal behaviour. Livestock Production Science, 85 (2004) 3-13.

Wallenbeck, A., Rydhmer, L., Thodberg., 2008. Maternal behaviour and performance in first-parity outdoor sows. Livestock Science, 116 (2008) 216-222.

Wischner, D., Kemper, N., Krieter, J., 2009. Nest-building behaviour in sows and consequences for pig husbandry. Livestock Science, 124 (2009) 1–8.

Yun, J., Swan, K-M., Vienola, K., Farmer, C., Oliviero, C., Peltoniemi, O., Valros, A., 2013. Nest-building in sows: Effects of farrowing housing on hormonal modulation of maternal characteristics. Applied Animal Behaviour Science, 148 (2013)

Zarrow, M., X., Farooq, A., Denenberg, V., H., Sawin, P. B., Ross, S., 1963. Maternal behaviour in the rabbit: endocrine control of maternal nest-building. Journal of Reproduction and Fertility, 6 (1963) 375-383.